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ABSTRACT

The requirements of PLATO IV, a computer based education system at the University of Illinois, have led to the development of an improved, digitally addressable, random access image selector and a digitally addressable, random access audio device. Both devices utilize pneumatically controlled mechanical binary adders to position the mecahnical loads. A recently invented, compact, electrically activated pneumatic control valve facilitates the conversion of digital signals to pneumatic signals which in turn control the mecahnical positioning devices. The prototype versions of these devices exhibit mechanical characteristics that should lead to compact, low-cost, commercially producible devices which will meet the needs of the PLATO IV system. (EMH)

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A DIGITALLY ADDRESSABLE RANDOM-ACCESS IMAGE SELECTOR AND RANDOM-ACCESS AUDIO SYSTEM

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A Digitally Addressable Random Access Image Selector and Random Access Audio System

by

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Abstract

The requirements of PLATO IV, a Computer-Based Education System being developed at the University of Illinois, have led to the development of an improved, digitally addressable, random access image selector and a digitally addressable, random access audio device. Both devices utilize pneumatically-controlled, mechanical binary adders to position the mechanical loads. A recently invented compact, electrically activated pneumatic control valve facilitates the conversion of digital signals into pneumatic signals which in turn control the mechanical positioning devices. The image selector is capable of accessing any of 256 images with a worst-case access time of 0.2 seconds. The audio device is capable of retrieving, from a magnetic disc record any of 4096 message units which comprise a total of 17 minutes of recorded message time, with a worst-case access time of 0.4 seconds. The prototype versions of these devices exhibit mechanical characteristics that should lead to compact, low-cost, commercially produceable devices which will meet the needs of the PLATO IV system.

Acknowledgment

A number of people contributed their talents to the development of the image selector and audio device described in this report. We would like to extend our appreciation to all members of the Coordinated Science Laboratory staff and the Computer-based Education Research Laboratory staff who helped in this work; our special thanks to go Mr. Lyle Bandy, Mr. Garrie Burr, Mr. Kenneth Merritt, and Dr. Frank Propst.

A Digitally Addressable Random Access Image Selector and Random Access Audio System

by

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I. Introduction

The University of Illinois design of PLATO IV, a computer-based education system, envisions a system which could reduce the total cost per student-contact hour by a large factor below any currently available system while maintaining the unique student terminal and systems software capabilities demonstrated in PLATO III (1,2,3). The educational and economic guidelines proposed for PLATO IV are described in a paper by Alpert and Bitzer (3) and the principal design features of the system are described in a paper by Bitzer and Skaperdas (4).

Initial steps toward implementing the development of a PLATO IV system at the University of Illinois have included the demonstration of the technical feasibility of certain key components of the system. Of particular importance is the demonstration of a prototype PLATO IV student terminal. Figure 1 presents an artist's illustration of a PLATO IV student console with keyset, plasma display panel, random access image projector, and auxiliary outputs for special equipment such as a random-access audio system. A detailed description of the operating format of this prototype terminal is given in a report by Stifle (5). The alpha-numeric and graphical display capability of the terminal will be provided by a 512 x 512 line plasma display panel similar to the type described in references(6,7). The image selector and associated projection system will allow prestored information to be projected onto the rear of the glass display panel.

This permits photographically stored information to be superimposed on the same image plane which contains the computer-generated information. The image selector is a digitally addressable, pneumatically driven device which moves a matrix or fiche of 256 - 1/4" images simultaneously along either of two Cartesian coordinate axes in order to position a desired image over a projection lens. The selector is required to exhibit a worst-case access time of 0.2 seconds, and it must position and repeat with an accuracy of $\pm$ 0.001 inches. A random-access audio device will also be available which retrieves and records messages by utilizing a polar coordinate positioning system that is also digitally addressed and pneumatically actuated. This system is presently designed to provide 4096 - 1/4 second, addressable message units for a total of 17 minutes of recorded message time; in addition, the device is required to provide a 0.2 - 0.4 second worst-case access time to any of the 4096 message units. Discussions concerning the educational rationale which has led to the incorporation of these retrieval devices in the PLATO IV terminal can be found in references (2,3).

Although various types of random-access image and audio retrieval systems presently exist, most of the currently available devices are extremely slow, cumbersome, and expensive. The purpose of this paper is to present a detailed, technical description of the pneumatically controlled random-access image selector and random-access audio system that were developed at the University of Illinois for the prototype PLATO IV terminal. As a result of several technical innovations, these two devices offer both improved performance and smaller physical size than currently available retrieval systems of similar function. In addition, the mechanical characteristics of these devices appear to be compatible with medium precision, low cost production techniques.

II. Digitally Controlled Linear and Angular Positioning

The principal mechanical tasks of the two systems being described in this paper is to position mass loads accurately with respect to fixed references in response to commands provided by a digital computer. The particular mechanical systems being considered are required to position, mass loads in the range of 1 kilogram along linear path lengths of the order of 12" or less, according to random digital commands. In the case of the image selector, the computer terminal specifications require the worst-case random access response time to be 0.2 - 0.4 seconds and the repeatable positioning accuracy to be within 0.001 inch of the desired true position. However, in the case of the audio system, the positioning tolerances are considerably less.

The mechanical load attached to the machanism in Figure 2 can be linearly displaced by this binary-input, linear-output device consisting of four pneumatic cyclinders mounted in series such that the lengths are additive. The stroke length of each piston in the series is weighted $1,2,4,\ldots,2^N$ units; N, in this case is equal to four. The pneumatic cylinders which comprise this device are of a conventional design, in which either side is pressurized while the other side is vented to the atmosphere. The two cylinder conditions, "fully extended" and "fully retracted", are the only conditions that are of interest in the present applications. For each cylinder in the series, the cylinder state can be controlled by means of an associated four-way pneumatic value which is activated by an electrical signal. Figure 3 illustrates the two cylinder states and the corresponding action of the four-way control valve.

In order to illustrate an example of digitally controlled, linear positioning, consider the series-mounted set of four pistons shown in Figure 4; in the situation shown, two pistors are fully retracted and two are fully extended. If the condition "fully extended" is represented by a "1" and the condition "fully retracted" is represented by a "0", the combination of cylinder states and therefore, the position of the load, is uniquely identified by the binary number 1100; i.e., the least significant bit (2^0) specifies the condition of the piston of unit length 1, the next bit position (2^1) specifies the condition of the piston of unit length 2, etc. If each of the respective four-way valves respond to appropriate electrical signals which represent four-bit binary position code, e.g., 1100, the electrical representation of a desired load position is converted into a mechanical action which places the load at that position. If a different code is applied to the valves, e.g., 1010, this new position is assumed without the necessity of the mechanism returning to a reference point. In a similar manner, the 16 unique combinations of piston states specified by the four-bit binary position code can be converted from electrical signals into pneumatic signals by electrically actuated four-way valves. These valves, in turn, pneumatically actuate the pistons and place the load at the position specified by the code. In the particular applications being considered, the piston lengths are successive, doublings of the smallest possible position change (i.e., the smallest piston length), e.g., the mechanism shown in Figure 4 provides for 16 equally spaced positions (1 unit length apart) along a linear path.

Figure 5 illustrates a simple extension of the linear positioning technique in order to provide a mechanism which is capable of moving a load to selected angular positions. The conversion from linear motion to angular motion can be obtained through the use of various devices, such as a rack and gear, a helical screw gear, as well as others. In the case of angular positioning with a rack and gear, the smallest required unit of angular change and the nature of the conversion device determines the series piston lengths, e.g., if $\alpha = 360°/N$ where $N = 2^n$ and n is an integer, a linear piston series (of unit length S = $r\alpha$ where r is the effective radius of the gear) can position the load mass at any one of 2^n angular positions which is an integral multiple of α from a fixed reference. A second particularly interesting linear-to-angular conversion mechanism will be described in Section IV as part of the discussion of the random access audio system.

In the past, most pneumatic positioning systems have been large and cumbersome, and there has existed very little motivation for reducing the gross size and cost of these mechanisms, especially the electrically activated control valves. For the systems being considered in this paper, however, reduction of size, cost, and the rate of fluid consumption are primary design factors. One of the principal innovations which has led to the realization of the potentially compact, low-cost systems described in Sections III and IV is the invention at the University of Illinois of a simple four-way pneumatic valve that can be actuated directly from digital logic, e.g., a computer output register. Each pneumatic cylinder in a series as that shown in Figure 4 is controlled by one of these pneumatic switches. The operation of this device is described with the aid of Figure 6(a) and 6(b). When the electrical input to the valve corresponds to a "1"; of "fully extended", the function of the pneumatic valve is to supply pressurized fluid to port A and to vent port B to the atmosphere. Similarly, the valve is required to supply pressurized fluid to port B and exhaust port A when the electrical input command is a "0" or "fully retracted". As shown in the cross-section view of the value shown in Figure 6(a), a cylindrical chamber formed by clamping two identical sections together is separated into two chambers (A and B) by a thin rubber diaphragm. A cylindrical riser extends into each chamber, through which pressurized fluid can flow from the source line. The output lines of the valve OLA and OLB which are connected to the actuating cylinder each have control ports OCA and OCB which can be either closed or vented to the atmosphere by the double acting solenoid plunger, i.e., if OCA is closed, the OCB is vented and vice versa. The minature solenoid valve is driven from a current source which responds to the position information provided to it by a computer or similar source of electrical signals.

In operation, the diaphragm seals either inlet port A or inlet port B in response to the position of the solenoid plunger. For the valve position shown in Figure 6(a), control port A is closed, thereby enabling airflow from the source inlet A through the chamber and into the cylinder so as to move the piston toward the "fully extended" state. Note that there is no static air loss in the control valve, since although chamber B is vented to the atmosphere, source inlet port B is sealed by the diaphragm. This position of the diaphragm is a stable position because the area of the diaphragm is substantially greater than the opening in the riser labeled inlet port B which in turn provides a differential force upon the diaphragm and causes it to seal off inlet port B. When the solenoid plunger is reversed, sealing OCB, the small dynamic leak through OCA momentarily lowers the pressure in Chamber A below that of Chamber B. The flexible diaphragm responds accordingly and assumes the complementary stable position sealing off inlet port A as shown in Figure 6(b). In this position, pressurized fluid is supplied to port B of the cylinder while port A is vented and the piston is forced to assume the "fully retracted" position. Note that the expenditure of pressurized fluid during a change of state is, for all practical purposes, the amount of pressurized fluid that was contained in the pressurized side of the cylinder, supply line, and valve chamber. To repeat, there is negligible pressurized fluid expenditure during periods when the mechanism is not changing state. Prototype models of this electrically controlled pneumatic switching device have been operated successfully under widely varying load conditions, cycling rates, and source pressures. For example, when using compressed air as the working fluid, the valves have been made to operate at source pressures as low as 1 psi; at 10 psi they have exhibited switching times of the order of 50 milliseconds. The mechanical tolerances necessary in operational devices of this type are such that the symmetrical chamber structures could be molded out of plastic, thereby providing the basis for a compact low-cost electrical-to-pneumatic signal converter and four-way valve.

III. The Design and Realization of a Digitally Addressed Random Access Image Selector

Figure 7 illustrates a configuration in which two sets of series-mounted pistons, operating at right angles, are mechanically coupled together to form an X-Y (Cartesian) positioning system. A system of this type can be used to position selected photographic images of an array or fiche over a fixed optical projection system. Consider a square array of N x N images where $N = 2^n$ and each image is 1/4" x 1/4". The image array is mounted in the rigid, rectangular frame which is free to slide in both the X and Y direction on the mutually perpendicular rails. One set of series-mounted pistons is attached to the X rail while the other set is attached to the Y rail. Both sets of pistons (X and Y) are fastened or referenced to the fixed table structure on which the projection system is mounted. The unit length of the pistons (i.e., the length of the shortest piston) is equal to the corresponding edge length of a single image, i.e., in this case L = 1/4". Positional control of the X and Y linkages is accomplished through electrically activated 4 way control valves that are attached to each of the cylinders.

In operation, the system requires the images which are to be selected or positioned over the reference point to be described by the binary representation of its X and Y coordinates with respect to the frame which holds the film. These position codes are applied, in parallel, to the control valves in the form of electrical signals from a computer. The resulting piston motion positions the film holder such that the desired image is placed over the projection aperature. Subsequent position commands move that film holder from position to position without the necessity of returning to a starting reference point after each command.

The accuracy and repeatability of this type of image selector are directly dependent upon two primary factors: 1) the mechanical precision of each component of the X-Y positioning mechanism, including the series linkages; and 2) the accuracy of the image array with respect to an array master which exhibits perfect uniformity in both alignment and size. Since the switching time of the valves is generally much smaller than the excursion time of the minimum movement position change, the access time of the mechanism is primarily determined by the mass of the load, the pressure of the actuating fluid, and the frictional drag of the bearings and the pneumatic pistons.

Figure 8 shows a prototype image selector and projection system that was recently fabricated and tested at the University of Illinois for installation in prototype PLATO IV terminals. The image array contains 256 (16 x 16) color or black and white images each 1/4" x 1/4". The series-mounted pistons in both the X and Y linkages have successive stroke lengths of 1/4", 1/2", 1", and 2". The control valves are connected appropriately to an 8-bit input register which receives electrical control signals from the output register of a digital computer or its equivalent. Using compressed air at 10 psi as the actuating fluid, the mechanism was exercised for 10^6 cycles (randomly selected positions) without experiencing any major failure conditions or excessive loss of positioning accuracy or repeatability. The worst-case access time for this particular mechanism was less than 0.2 seconds and the positioning accuracy and repeatability remained within + .001 inches. Figure 9 is a block diagram of a typical image selector installation.

IV. The Design and Realization of a Digitally Addressable Random Access Audio System

Two types of computer controlled audio devices have been recently developed at the University of Illinois Computer-Based Education Research Laboratory. The first is a centrally located, random access audio bank used for distributing extremely high quality audio messages to large numbers of students, each student having individual access to a string of messages without interference by any other user. This system, developed by B. Voth (8), appears to be best suited for applications in which large numbers of users are accessing similar material from terminals located in near proximity, e.g., the same building. The second device which will be described here in detail is expected to be compact and inexpensive enough to be located at or near a student terminal (e.g., a PLATO IV terminal) and will provide high quality randomly-accessed audio messages to only that terminal. The device should be especially well suited to the needs of the remote, user terminal.

Figure 10 illustrates the basic audio components which will be used in the system being described. Audio messages are recorded on a thin mylar-based magnetic recording material cut in the form of a disk (typically 12 inches in diameter). The disk is mounted on a high moment of inertia, rim driven turntable which rotates with an angular velocity of 1 revolution per 8 seconds. The messages are recorded on successive circular tracks (360°) with each track subdivided into 32 sectors or message units. The location of a message unit with respect to a reference point on the disk is identified by the binary numbers which represent the appropriate track and sector within that track. Access to any particular message unit (i.e., track and sector) within a worst case retrieval time of 0.4

seconds requires both radial and angular positioning, since using only radial positioning would provide a worst case retrieval time of 8 seconds. Digitally controlled radial positioning of a record/playback head can be accomplished in much the same manner as that used in the image selector. The magnetic head is attached to one end of a set of series-mounted pneumatic pistons; the other end of the piston linkage is fixed with respect to the turntable. In the case of 64 radial tracks, a set of six series mounted pistons is used; the length of the shortest piston throw is equal to the inter-track spacing. The tracks in this case are identified by a 6-bit binary address.

The rapid angular positioning that is needed in order to bring a desired sector (message unit) in contact with the playback head can be achieved by rapidly changing the angular position of the low moment of inertia mylar disk with respect to the high moment of inertia turntable. This procedure preserves the highly stable constant velocity of the turntable necessary for high quality audio while at the same time it provides a means of rapidly positioning the sector with respect to the magnetic head.

The angular displacement of the mylar disk with respect to the turntable can be accomplished through linear translation of a specially grooved, axial shaft as illustrated in Figure 11. Figure 11(a) shows an axial shaft with a vertical groove, fitted into the keyed center hole of the turntable. As the turntable rotates, the shaft is forced to rotate with it. However, the shaft is free to move up or down (i.e., along the Z coordinate) without disturbing the rotation of the turntable. Figure 11(b) illustrates a helical groove which is also cut into this shaft. In Figure 11(c), the mylar disk is shown attached to a hub which is keyed only into the helical groove of the axial shaft. If the axial shaft remains stationary with respect to the Z coordinate and if the hub and attached disk remain in contact with the turntable, the angular position of the disk with respect to the turntable remains fixed. However, if the axial shaft undergoes a linear translation along the Z coordinate while the disk and hub remain in contact with the turntable, the disk is angularly displaced with respect to its original position on the turntable. The angular displacement $\Delta\phi$ is related to the linear translation ΔZ by the equation $\Delta\phi = \frac{\Delta Z}{\gamma}$ where γ is the pitch of the helical groove. Suitable bearings and sliding surfaces are introduced in order to allow the mylar disk to rotate freely with respect to the turntable while remaining in contact with it. In summary, the mechanism illustrated in Figure 11(c) enables a low moment of inertia mylar disk to be rotated rapidly (to any angular position) with respect to a slow moving, high moment of inertia turntable without significantly disturbing the constant angular velocity of the turntable. As a result, any message unit (or sector) on the recording media can be rapidly accessed by radially positioning a magnetic head while simultaneously positioning the recording media in angle in order to bring the desired sector in contact with the magnetic head. When the desired track and sector have been selected, the angular velocity of the recording media is again equal to the constant angular of the turntable, thus allowing a message unit to be played back or recorded by the magnetic head. In the case where there are 32 equal length sectors per track, the axial shaft can be translated appropriately by using a set of five electrically controlled, series-mounted pneumatic cylinders where the length of the shortest throw (i.e., the unit length) is $\Delta Z = 360° \cdot \frac{\gamma}{32}$

In order to select a given sector at any point in time, it is necessary for a digital controller to know where the angular reference mark of the disk ($\phi_d=0°$) is in relation to the magnetic head. One manner in which this can be accomplished is by providing equi-spaced optical or magnetic markers on the circumference of the turntable which correspond to the sector boundaries; a special mark is used to denote the angular reference point of the turntable ($\phi_t = 0°$). A detector which is positioned along the fixed radial path of the magnetic head, senses the turntable markers and correspondingly triggers a digital counter; the counter is cleared whenever the turntable reference position is sensed. Consequently, the counter indicates the angular position of the turntable to within one sector. For simplicity, assume that the angular reference points of the disk and the turntable coincide when the axial shaft is in maximum "up" or positive Z position, see Figure 12(a). In order to position a desired sector, r, at the magnetic head when the counter indicates that sector q is presently in that position, the address, q, of the current sector is subtracted from the address, r, of the desired sector, and the difference r-q specifies the amount of angular rotation that is required. An example where r = 14 and q = 3 is illustrated in Figures 12(a) and 12(b). This example assumes an instantaneous change in angular position; in actual practice, the digital controller much be designed to correct for conditions where the finite angular selection time would case an erroneous sector to be selected.

Figure 13 is a photograph of the prototype random access audio system presently being tested on the PLATO system. Messages are recorded on 64 radial tracks with each track being divided into 16 equal sectors. The 12 inch, rim-driven turntable, which moves at an angular velocity of 1 revolution per 8 seconds, provides for 512 seconds (8 1/2 minutes) of recorded audio per disk at an average effective tape speed of 4 1/2 inches per second (i.e., the average track length is approximately 36 inches). A suitable dual track magnetic head can also be used, in order to provide 128 tracks of recorded material, for a total of 17 minutes of recorded message time. In order to avoid unnecessary wear, the magnetic head is brought into contact with recording material only after the required positioning motion is completed; at the end of a message sequence the head is lifted from the material. Radial access to a particular track is obtained with the radial positioning arm shown in Figure 14. A set of six series-mounted pneumatic cylinders of unit length 0.055 inches is controlled by a corresponding set of 6 valves which are driven by the digital controller. Access to a particular sector is obtained with a helically grooved, axial shaft that is translated by a set of four series mounted cylinders. The angular position of the turntable is sensed by a photodiode which observes optical markers along the circumference of the turntable. The sliding magnetic head unit is raised and lowered with respect to the recording material by means of a solenoid which is electrically activated by the controller.

In order to perform a message retrieval, the digital controller receives 14 bits of information from a computer; 6 bits to specify the track 4 bits to specify the sector, and 4 bits to specify the message length in units of sectors. Figure 15 shows a block diagram of the digital controller which is presently used to operate the prototype audio device. The prototype audio system shown in Figure 13 is currently undergoing evaluation on the PLATO III system. The unit operates from a 15 psi clean air source. When operating at an average rate of one random audio selection every 2 seconds, the unit consumes air at the rate of .05 ft.^{3} per minute at 15 psi. The worst-case mechanical access time of the unit is 0.3 seconds; however in this model additional access time is added via the software in order to compensate for the effects of the finite angular selection time. The recording disks are cut from standard mylar base, magnetic recording material which is available in bulk form. Mounting the recording disks on the turntable is equivalent in difficulty to placing a 33 1/3 phonograph record on a standard turntable. The wear characteristics of the recording material used in this device appear to be no more serious than those experienced in standard magnetic tape recording equipment.

V. Summary

The requirements of the PLATO IV student terminal have led to the development of an improved, digitally addressable, random access image selector and a digitally addressable random access audio device. The technological feasibility of these devices has been shown at the University of Illinois via prototype units which meet the PLATO IV operating specifications; however, specific confirmation of the low, unit cost goals awaits further experience with pilot production models. The mechanical characteristics of both the image selector and the audio device described in this paper however, do appear to lend themselves to medium precision, low cost production techniques. In addition, the innovations which led to the realization of these particular devices may also be applicable to many other systems applications which involve computer controlled mechanical retrieval or positioning tasks.

References

1. D. L. Bitzer, R. W. Blomme, B. A. Sherwood, P. Tenczar, "The PLATO System and Science Education," presented at the Conference on Computers in Undergraduate Science Education, Illinois Institute of Technology, August, 1970; also as CERL Report X-17, Computer-Based Education Research Laboratory, University of Illinois, Urbana, Illinois, August, 1970.

2. D. L. Bitzer, B. L. Hicks, R. L. Johnson, and E. R. Lyman, "The PLATO System: Current Research and Developments," IEEE Transactions on Human Factors in Electronics, Vol. HFE-8, No. 2, June 1967.

3. D. Alpert, D. L. Bitzer, "Advances in Computer-Based Education," Science, 20 March, 1970, Volume 167, pp. 1582-1590; also as CERL Report X-10, Computer-Based Education Research Laboratory, University of Illinois, Urbana, Illinois, July, 1969.

4. D. L. Bitzer, D. Skaperdas, "PLATO IV - An Economically Viable Large-Scale Computer-Based Education System," presented at the National Electronics Conference, Chicago (December 1968); also appears as CERL Report X-5, Computer-Based Education Research Laboratory, University of Illinois, Urbana, Illinois, February, 1969.

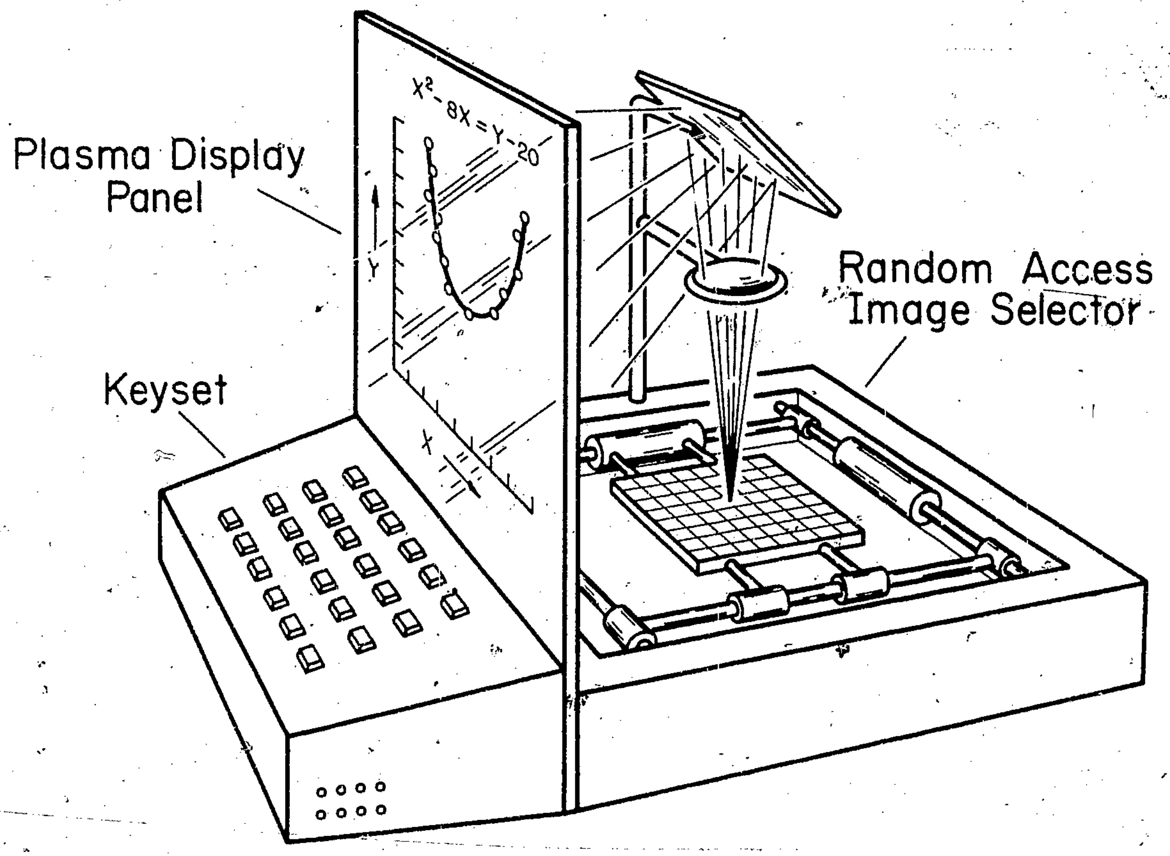
5. J. Stifle, "A Plasma Display Terminal," CSL Report R-460, Coordinated Science Laboratory, University of Illinois, Urbana, Illinois, March, 1970.

6. D. L. Bitzer and H. G. Slottow, "The Plasma Display Panel - A Digitally Addressable Display with Inherent Memory," Proceedings of the Fall Joint Computer Conference, 1966, pp. 541-547.

7. D. L. Bitzer and H. G. Slottow, "Principles and Applications of the Plasma Display Panel," Proceedings of the O.A.R. Research Application Conference, Office of Aerospace Research, Arlington, Va., March 1968; also in the Proceedings of the 1968 Microelectronics Symposium IEEE, St. Louis, 1968.

8. B. Voth, "A Shared Audio Hardware Response System," CERL Report X-8, Computer-Based Education Research Laboratory, University of Illinois, Urbana, Illinois, July 1969.

Student Console



Schematic Diagram of Student Console

GS-545

FIGURE 1

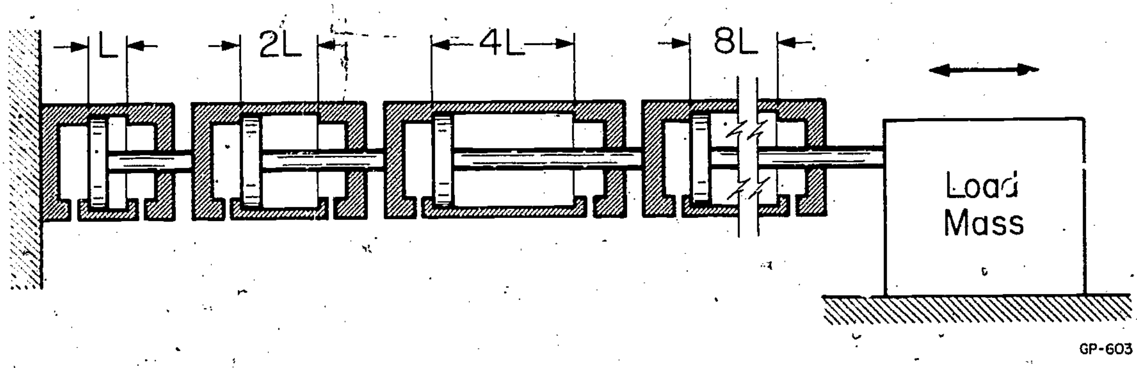


FIGURE 2

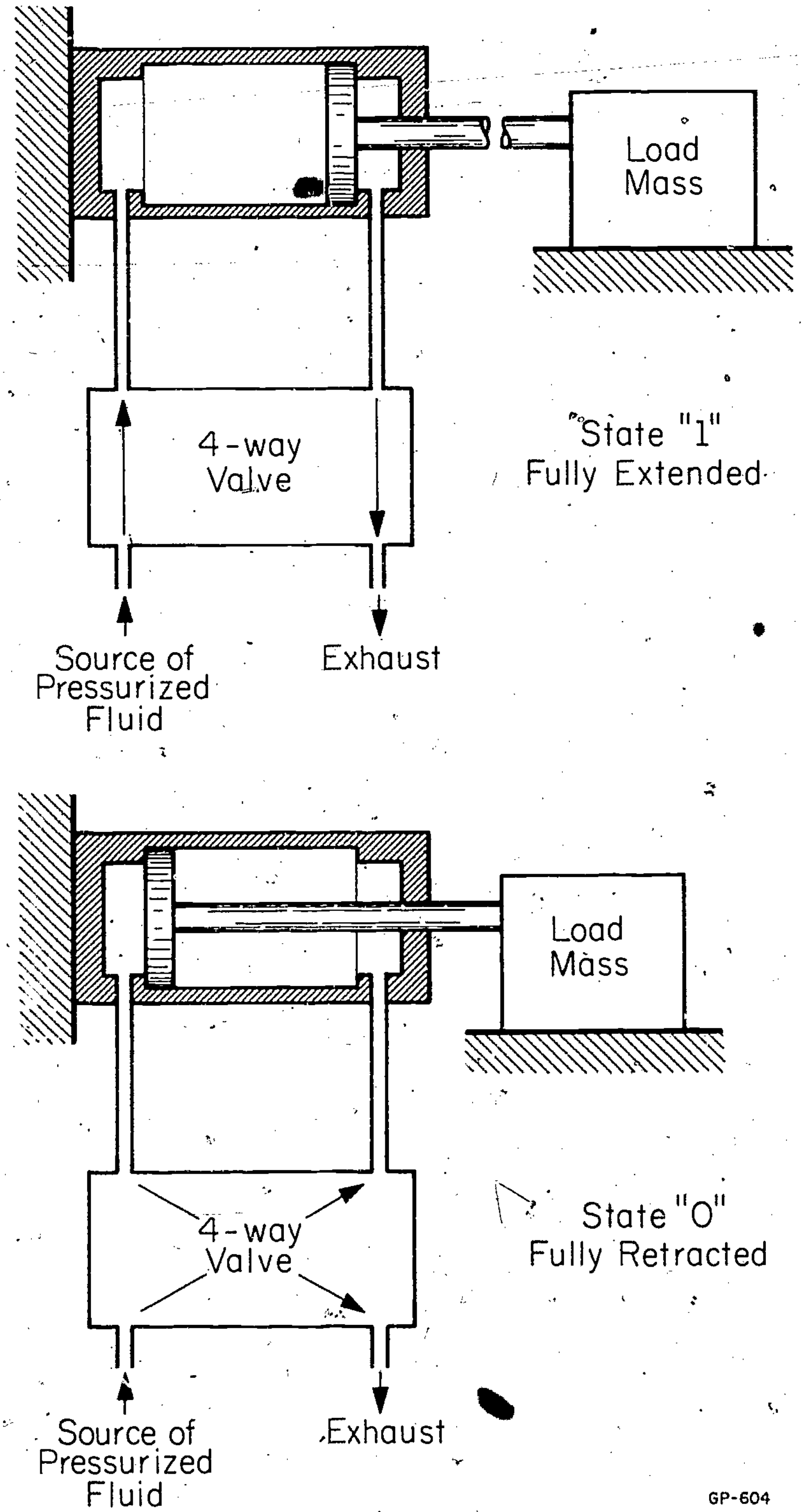

Load
Mass
4-way
Valve
State "1"
Fully Extended
Source of
Pressurized
Fluid
Exhaust
Load
Mass
4-way
Valve
State "0"
Fully Retracted
Source of
Pressurized
Fluid
Exhaust
GP-604

FIGURE 3

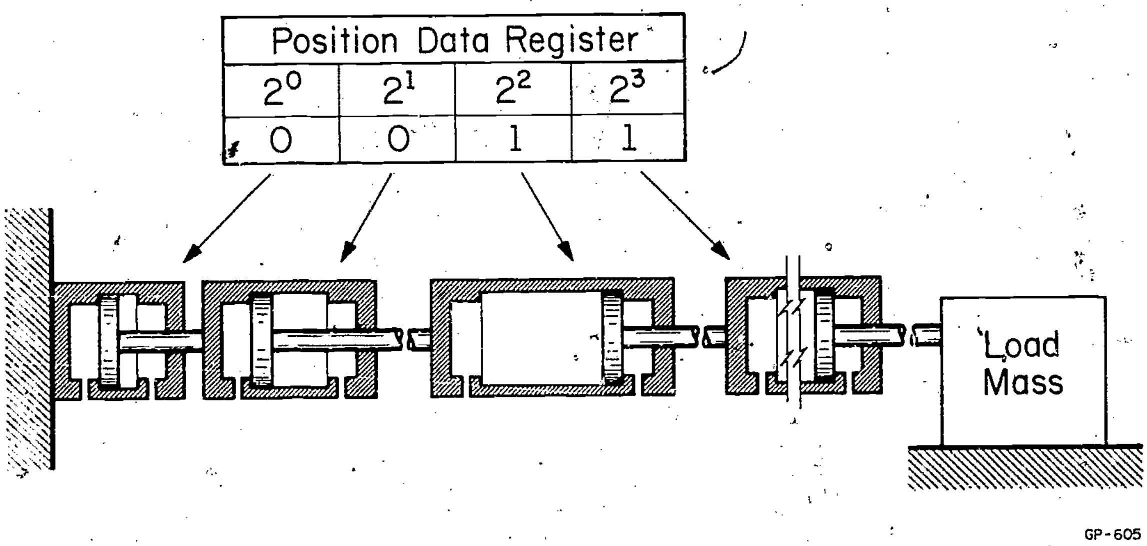


FIGURE 4

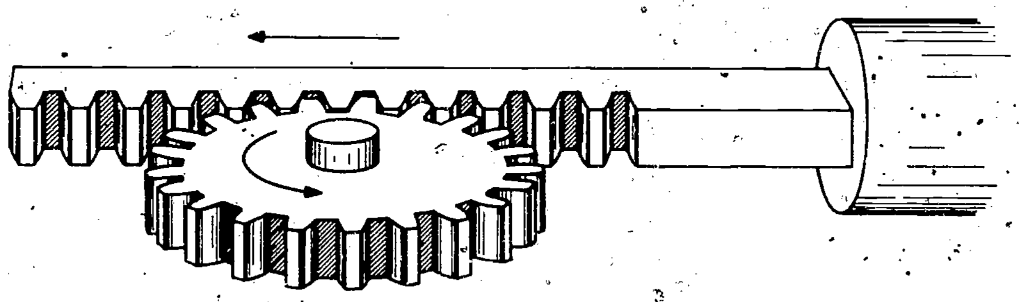


FIGURE 5

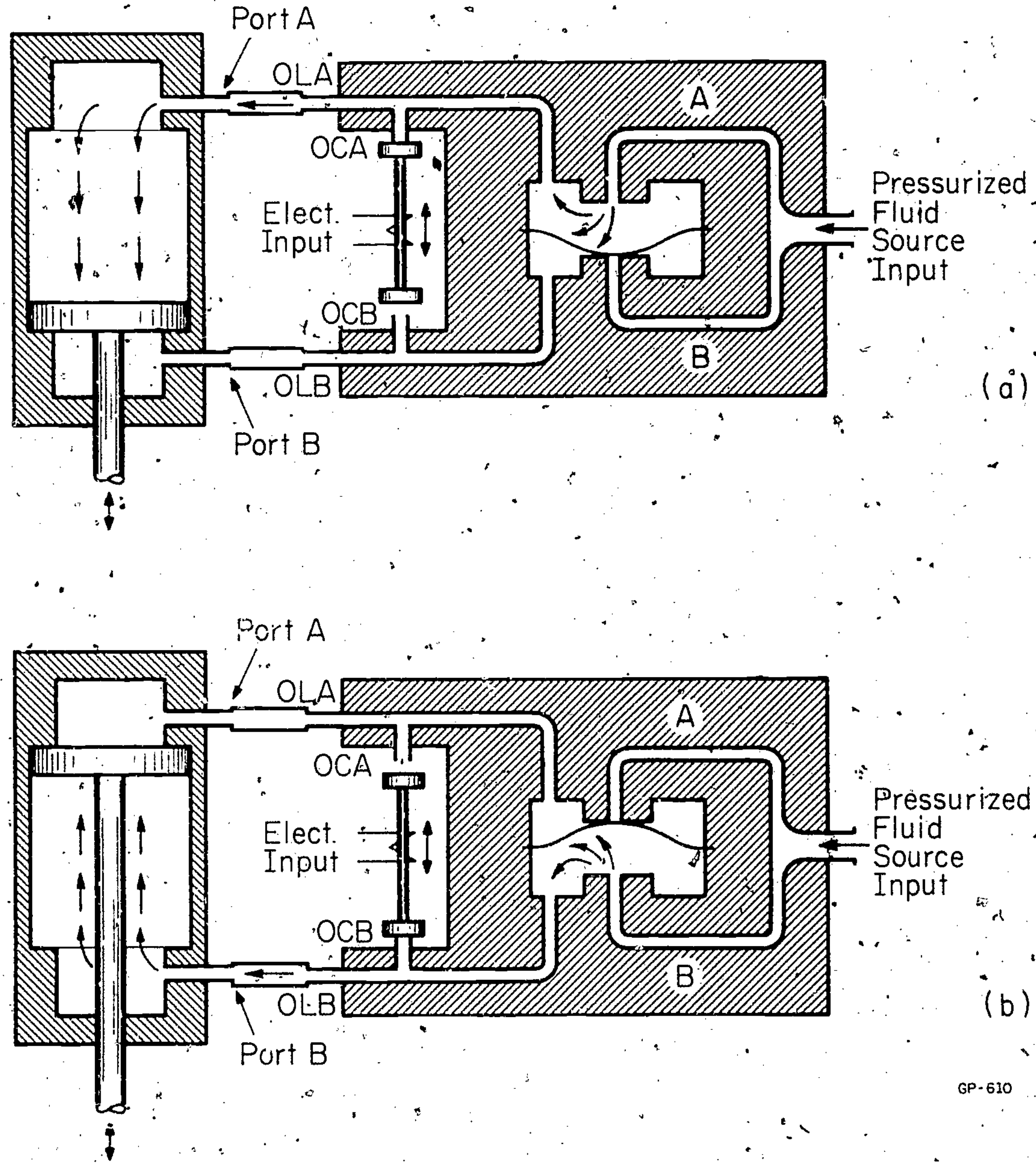

Port A
OLA
A
OCA
Elect.
Input
Pressurized
Fluid
Source
Input
OCB
B
OLB
Port B
(a)
Port A
OLA
A
OCA
Elect.
Input
Pressurized
Fluid
Source
Input
OCB
B
OLB
Port B
(b)
GP-610

FIGURE 6

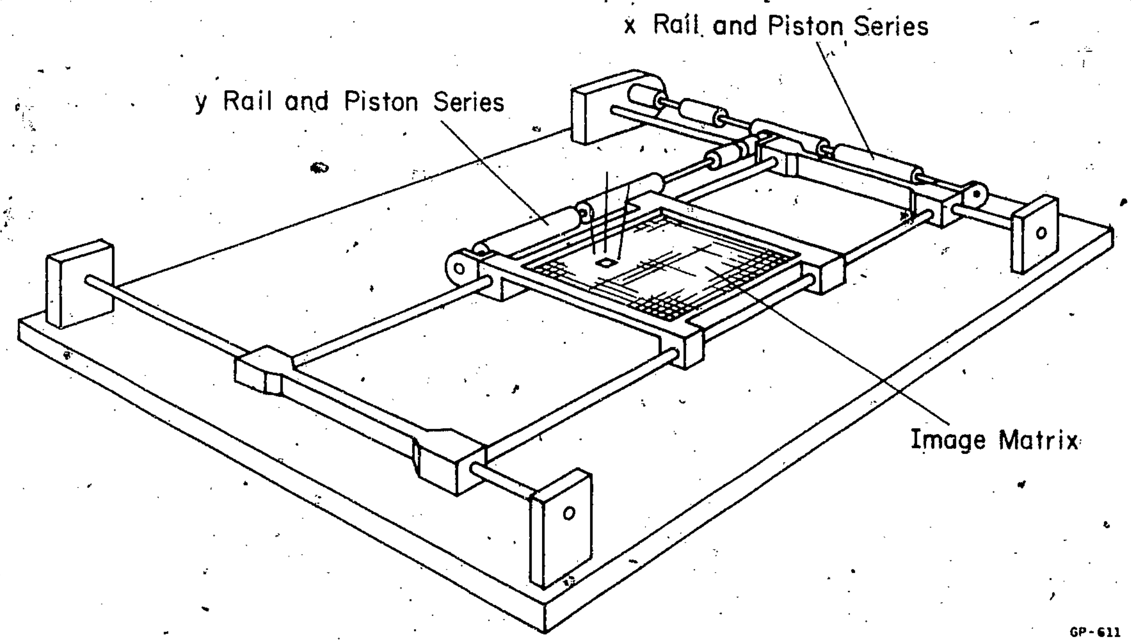

x Rail and Piston Series
y Rail and Piston Series
Image Matrix
GP-611

FIGURE 7

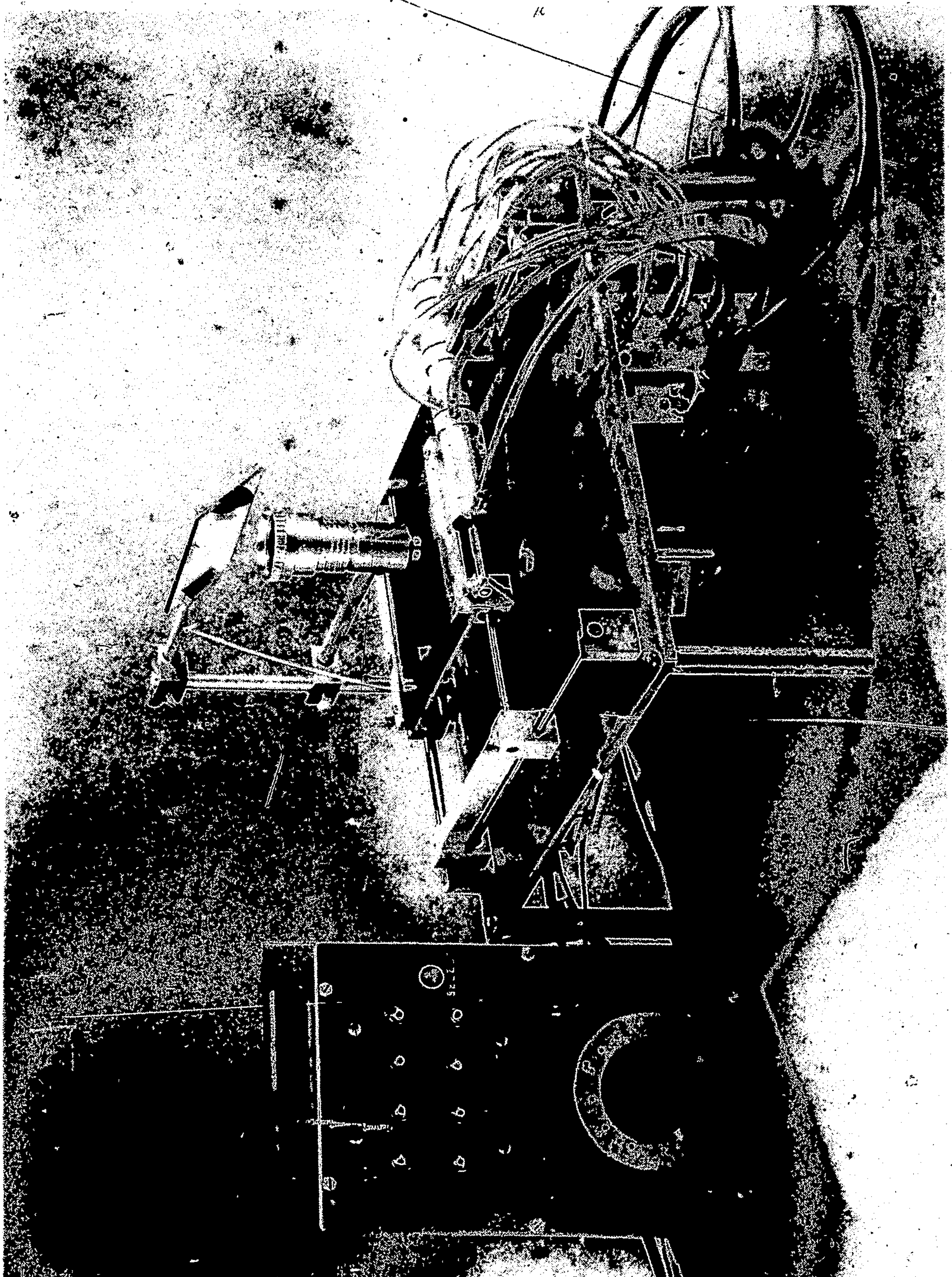


FIGURE 8

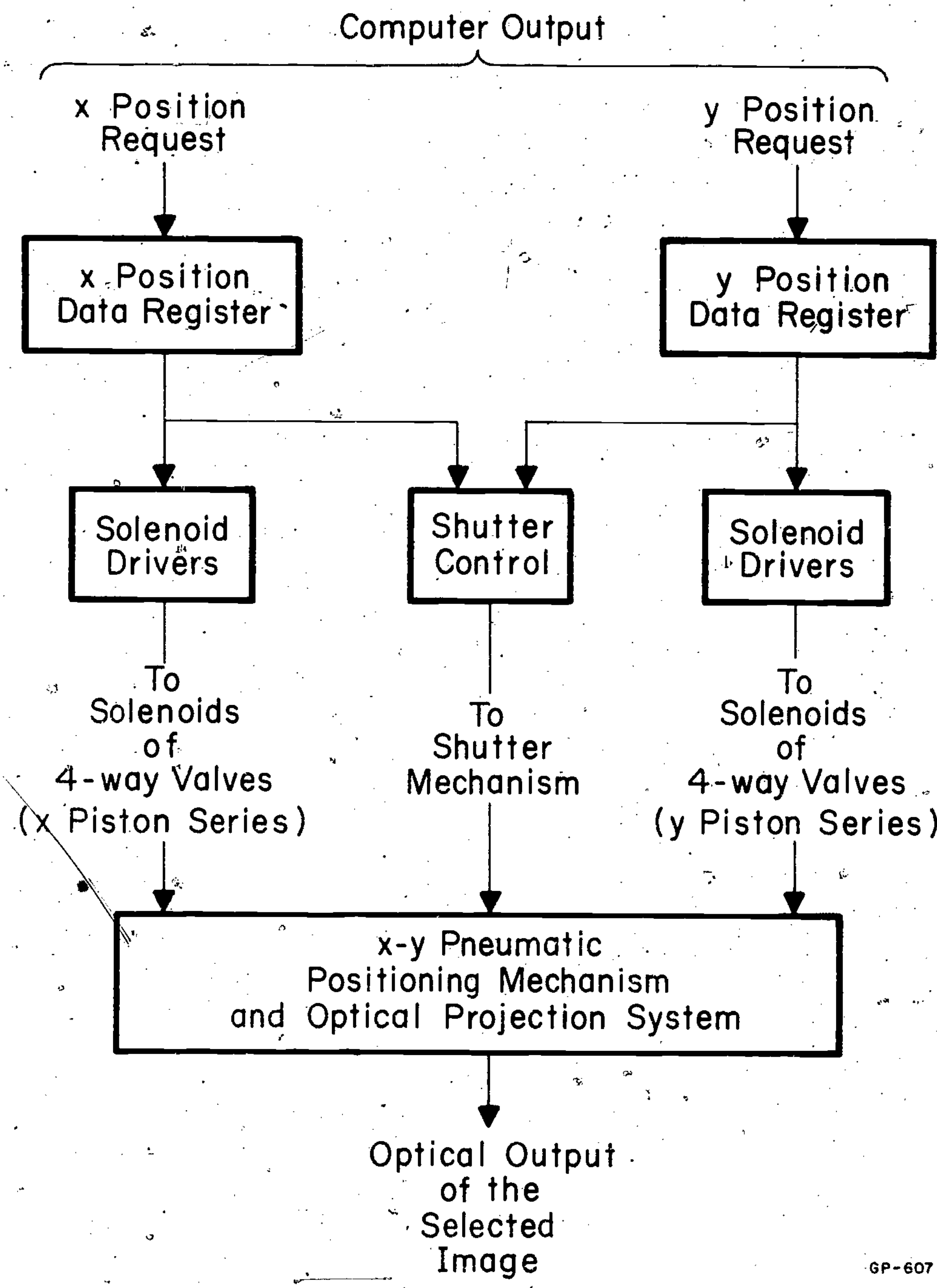

Computer Output
x Position Request
y Position Request
x Position Data Register
y Position Data Register
Solenoid Drivers
Shutter Control
Solenoid Drivers
To Solenoids of 4-way Valves (x Piston Series)
To Shutter Mechanism
To Solenoids of 4-way Valves (y Piston Series)
x-y Pneumatic Positioning Mechanism and Optical Projection System
Optical Output of the Selected Image
GP-607

FIGURE 9

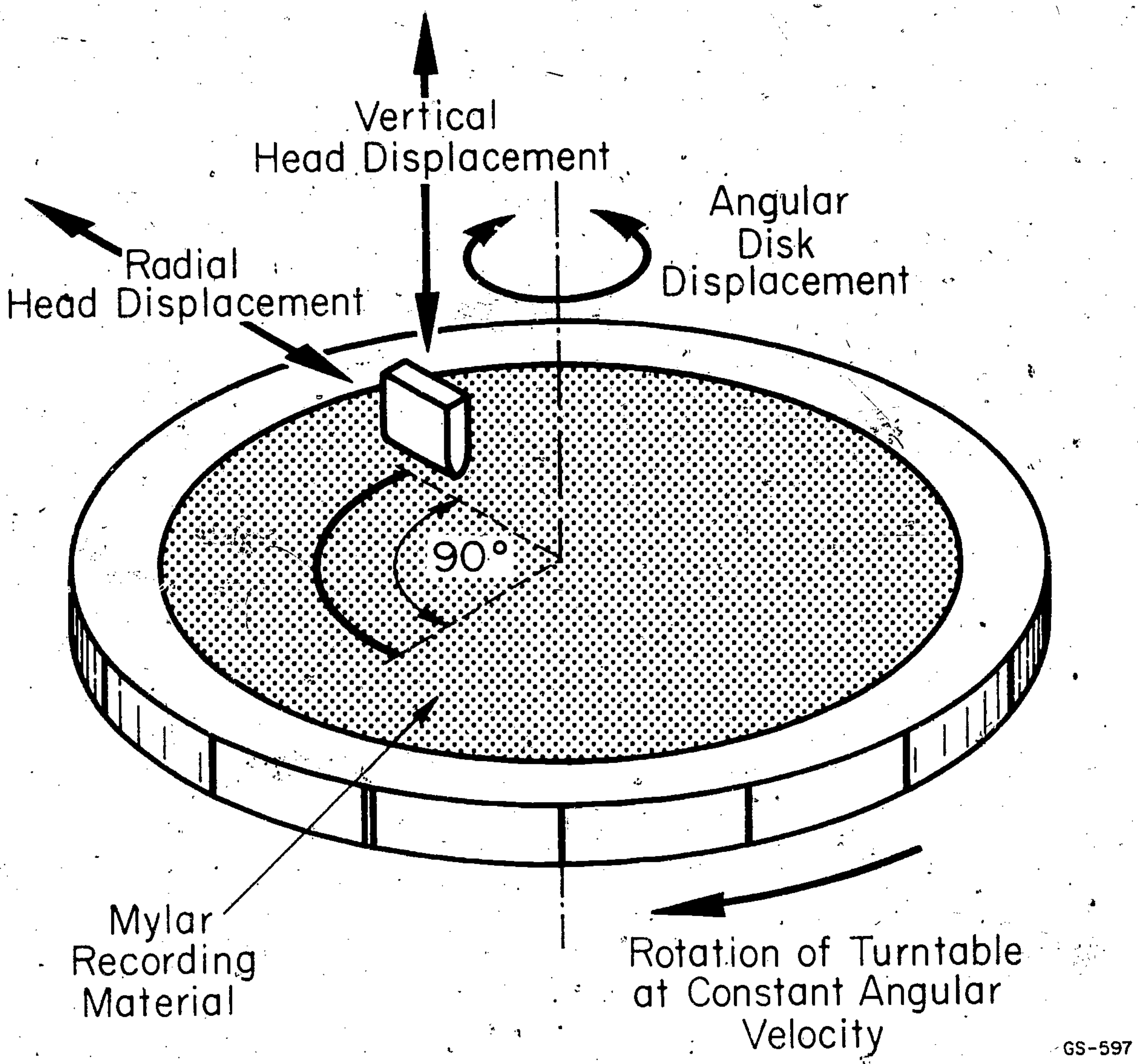

Vertical
Head Displacement
Angular
Disk
Displacement
Radial
Head Displacement
90°
Mylar
Recording
Material
Rotation of Turntable
at Constant Angular
Velocity
GS-597

FIGURE 10

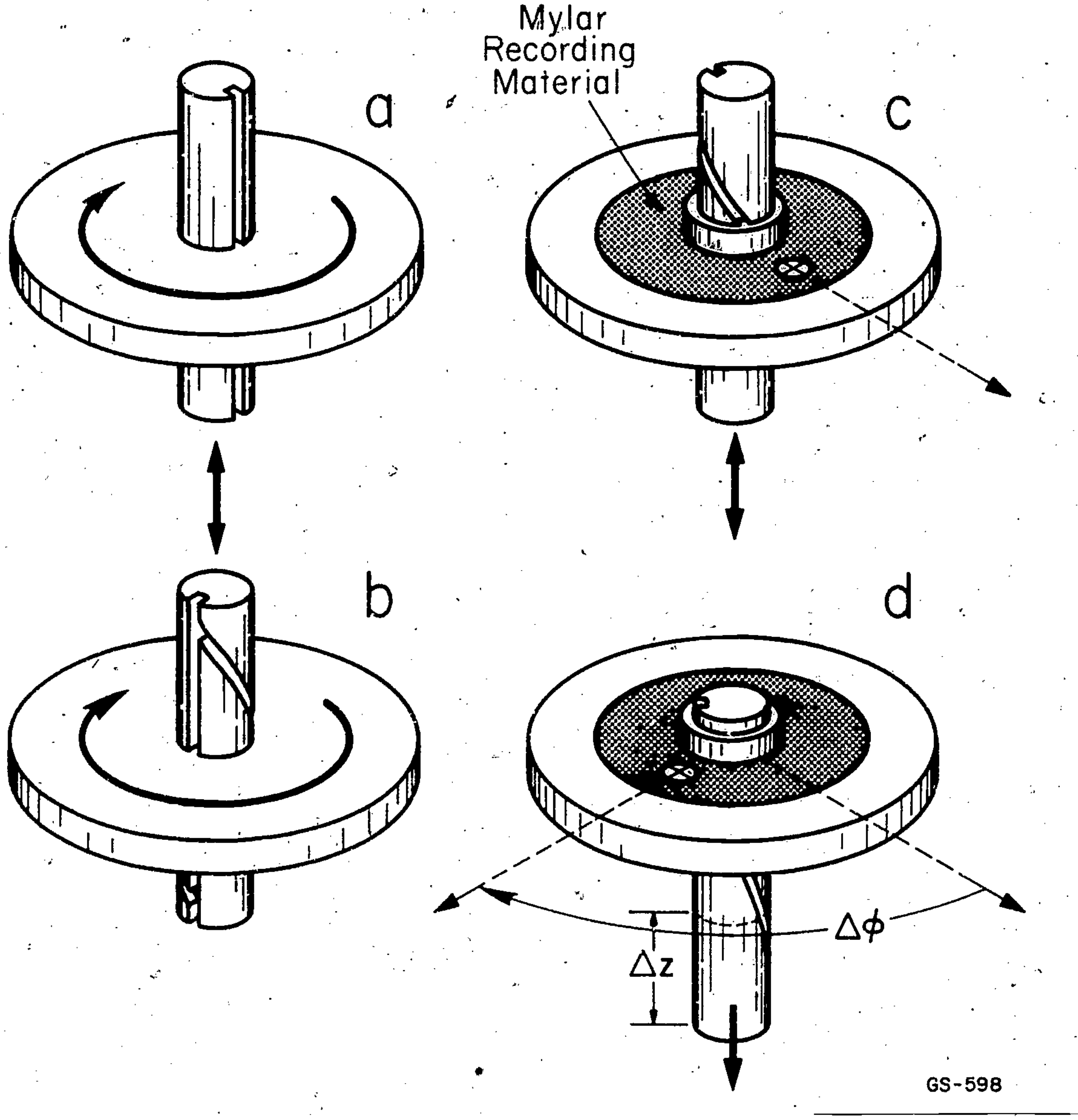
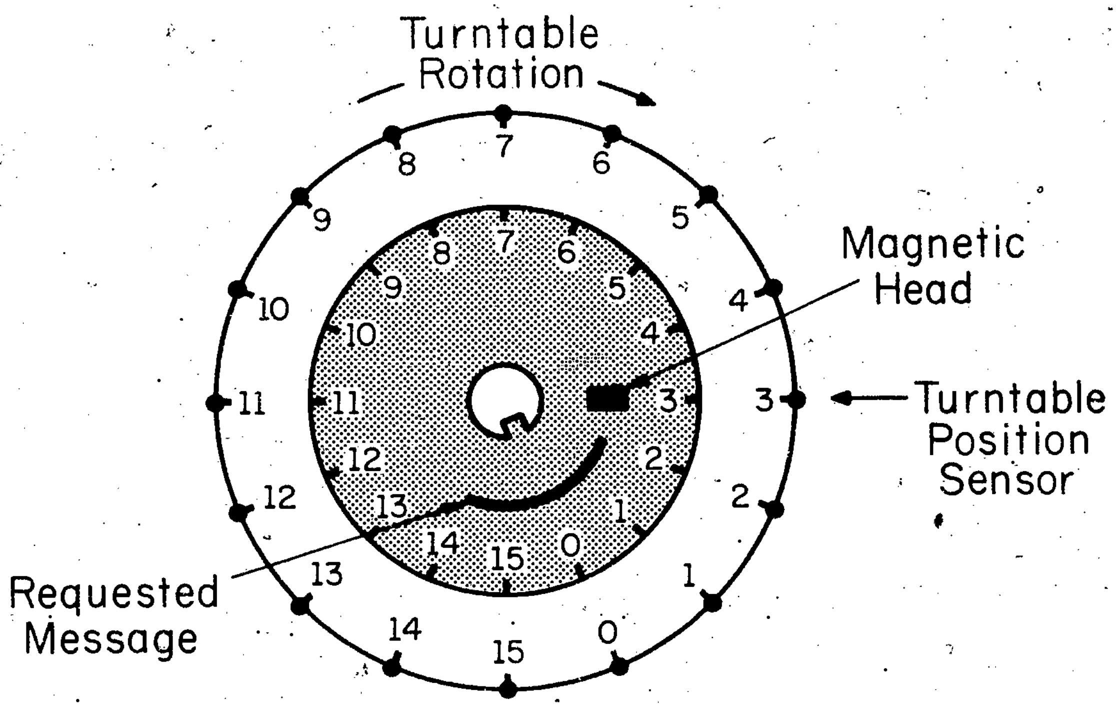
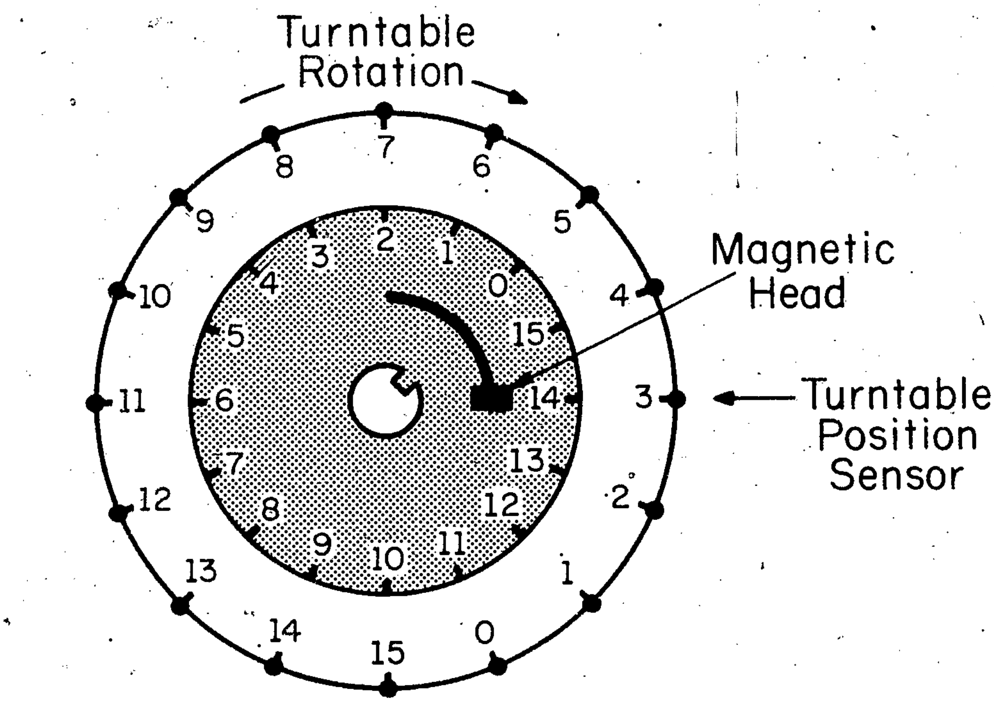


FIGURE 11



(a) Before Request



(b) After Request
(assuming instantaneous acquisition)

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FIGURE 12

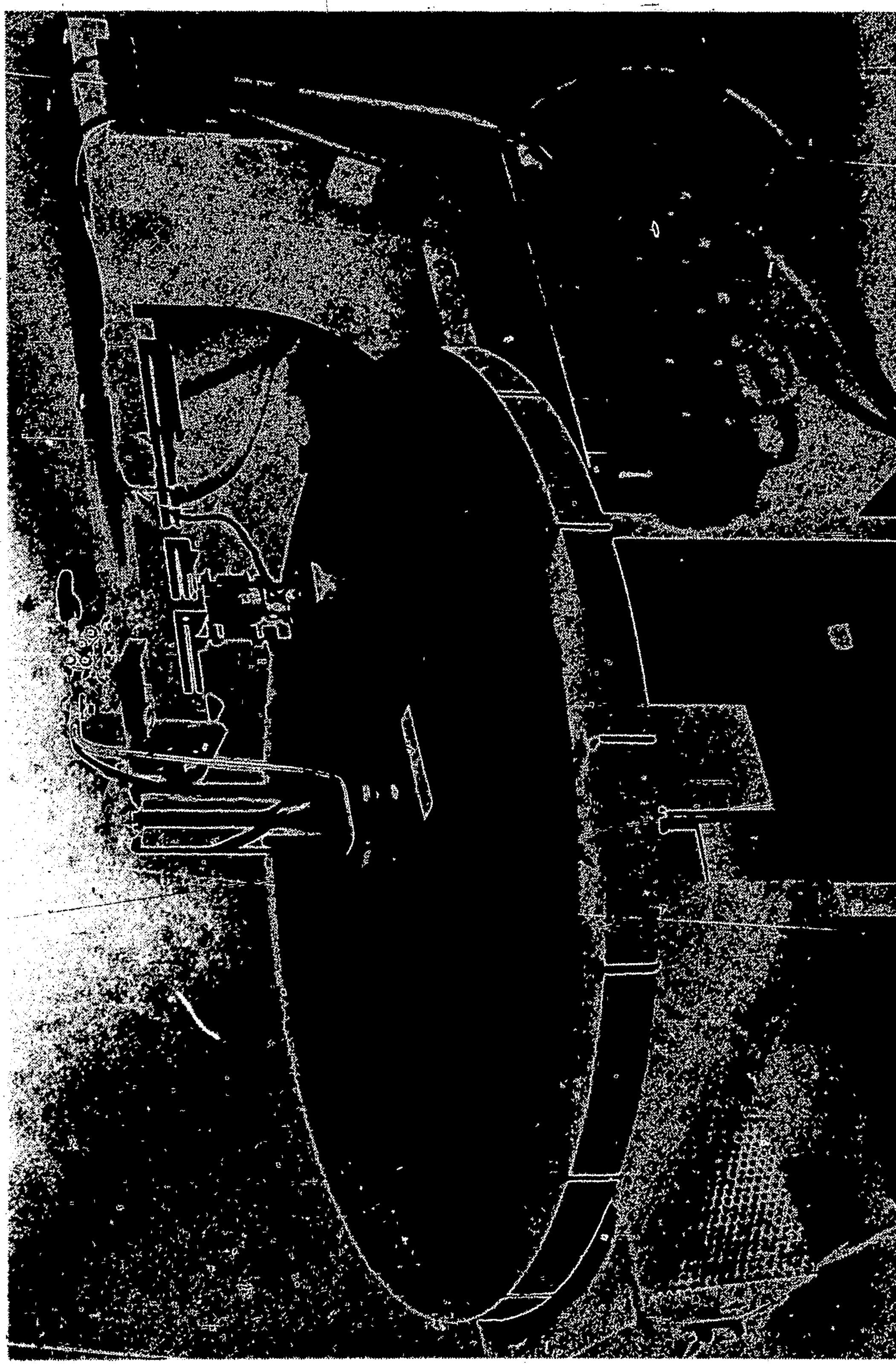

FIGURE 13

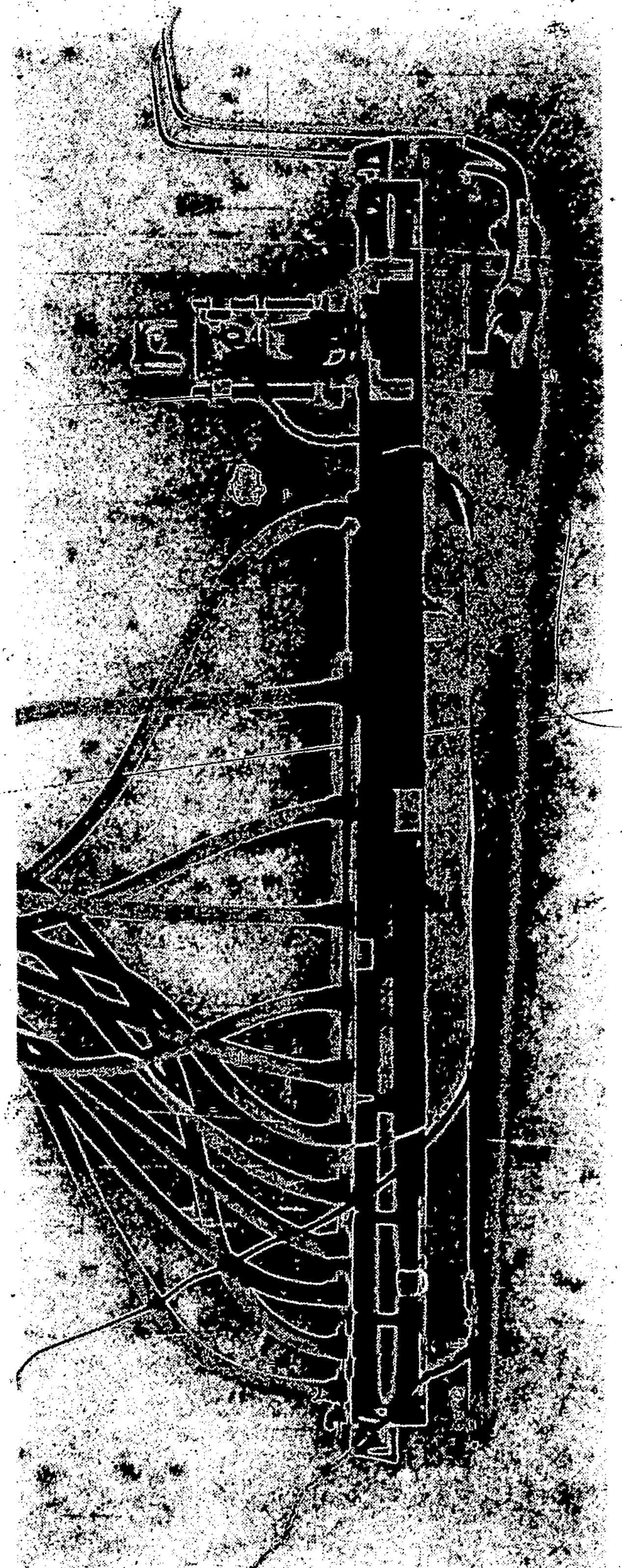

FIGURE 14

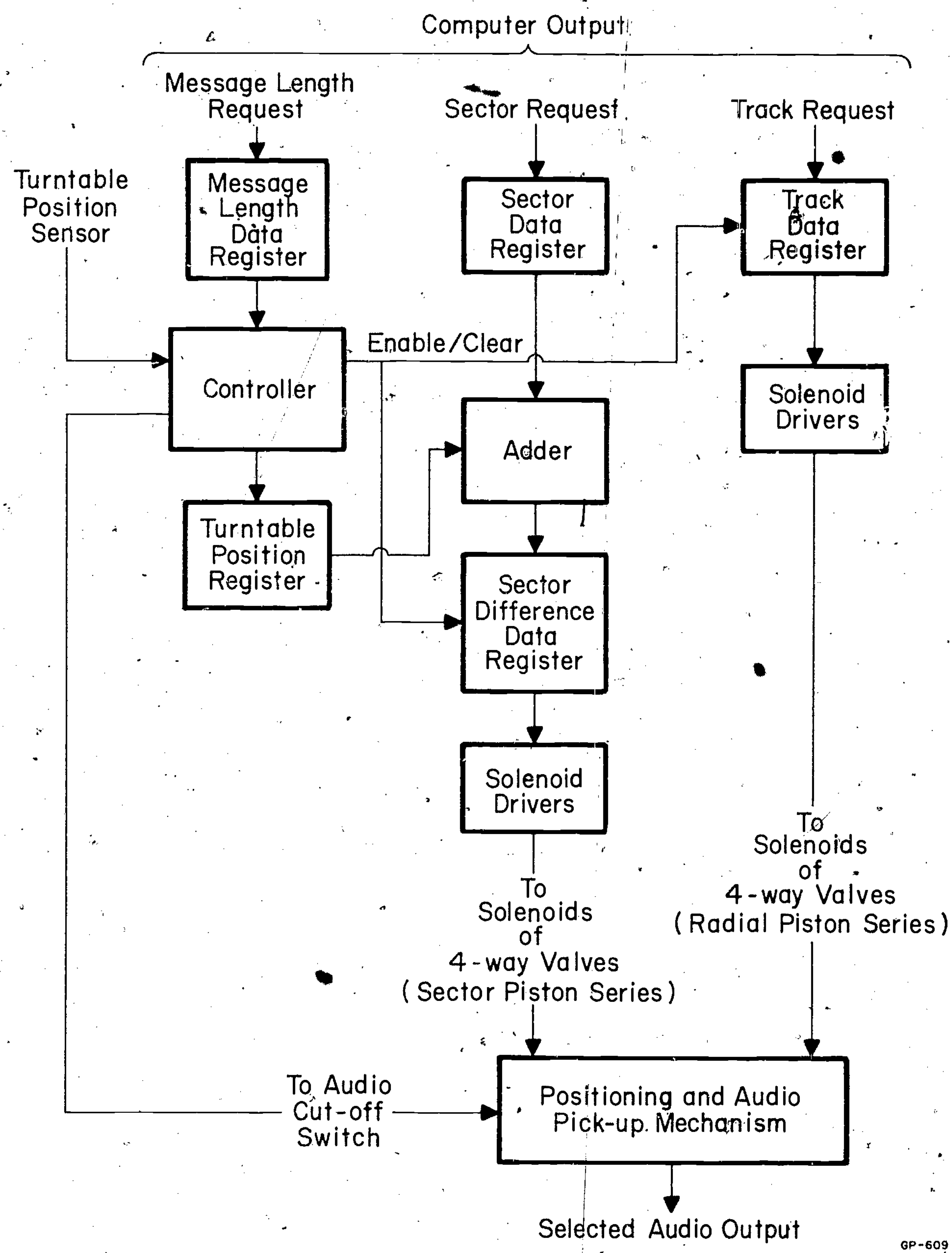
Computer Output
Message Length Request
Sector Request
Track Request
Turntable Position Sensor
Message Length Data Register
Sector Data Register
Track Data Register
Controller
Enable/Clear
Adder
Solenoid Drivers
Turntable Position Register
Sector Difference Data Register
Solenoid Drivers
To Solenoids of 4-way Valves (Radial Piston Series)
To Solenoids of 4-way Valves (Sector Piston Series)
To Audio Cut-off Switch
Positioning and Audio Pick-up Mechanism
Selected Audio Output
GP-609

FIGURE 15